Principles of Electronic Image Processing – Signals

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Experimental Television Center, 1978-80

> "The universe as we knew it until now was constructed on information of light, which reached our eyes and provided a model of the conscious universe. But now, with radio astronomy, we are getting a very different notion of our universe. First of all, we receive information which is not visible. It's not points or spheres anymore. It's energy which is not a permanent state; it is permuting, as a matter of fact, all the time. So that suddenly, through the instruments we have, we are reconstructing the universe in some visual sense, because eventually we translate radio waves into some visual model. We are now trying to visualize space which exists only as electromagnetic forces…It's the notion of the organization of energy in time that for me is the key to all sorts of changes within life."
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> Woody Vasulka, in Johanna Gill, Video: State of the Art 1976

SIGNALS

As a kinetic as well as an electronic form, video concerns itself with the time/space equation. Video image movement occurs within a predetermined space, and the process of change, by definition, is a temporal event occupying a specific length of time. Changes in the time frame or time base of the signals which define the image result in changes in the duration of images and in the locations of sections of images within the two dimensional space of the image's display. On the level of electronics, the very construction of the video image, its generation as well as its display, is time dependent. The composition of the signal, then, defines the visual nature of the image as it exists in time; it dictates both the appearance of the single "still" image, which exists within a specific length of time, and its behavior through time.

On a primary level, the signal can be viewed as the art-making material; the creation of an electronic image is an architectural process and constructed in time. The signal refers to changes in energy levels and reveals a physical nature by forming and influencing images. Specific devices in an electronic image processing system perform specific functions or operations on signals, generating and altering the signals, or codes, and therefore the resulting images. In this way the hardware of the system can be viewed, in part, as a "carrier of aesthetic definitions." There are several general categories of signals specified by the processing system which include video, audio, control, and synchronizing or timing signals: as shall be seen, signals may perform functions within several categories. One signal, for example, can influence an image and also produce a sound.

The term "signal," derived from the Latin signum meaning sign, refers in a general sense to the use of conventional symbols which refer to a verbal description of a concept or event. A signal then is a translation of the description of an event from one set of symbols to another set of codes. It is the representation of the event. The signal conveys information concerning the state of the event in any given instant through time. Video images are codes of information conveyed by signals. The specific video picture information conveyed by a signal is in the form of changes in voltage; changes in voltage dictate changes in the information being carried. Voltage changes can be categorized in terms of changes of strength, increased or decreased voltage, and changes of direction, alternating or direct current signals.

Electricity is usually defined as the orderly movement of electrons through a conductive material. When a voltage is applied to a conductor, a force field is established which causes electron movement and therefore electrical energy. The rate at which electrons move past a given point is a measure of current strength expressed in ampheres or amps. When a current of one amp flows through a conductor, 6x 10 raised to the 18th power

electrons are passing a given point each second. Electrons move only when an unbalanced electrical force or potential difference is present; voltage is a measure of the force causing electronic motion and is often described as electrical force or pressure. Ground is a reference point which has zero potential energy or zero volts. Because of the properties and dimensions of the conductive material, there is a resistance to the flow of electrons. Resistance is often likened to friction and is measured in ohms. It refers to the impedance of a current flow and results in the dissipation of power in the form of heat. Although the degree of resistance is dependent on the nature of the material, the resistance of any given material is constant.

Ohm’s Law egresses the relationship between current, resistance, and voltage; it states that voltage equals current, measured in amps (I), multiplied by resistance, measured in ohms (R).Because the resistance of material does not change, voltage is proportional to current. Increases or decreases in voltage simultaneously produce proportional in creases or decreases in current. A watt is a unit of electrical power produced when one volt causes a current of one amp to flow through a circuit.

Two of the effects of electrical current are heat and magnetism. The resistance of the conductive material to the flow of electrons produces heat; this is easily demonstrated by the warmth of an incandescent electric light bulb. An electrical current also induces a magnetic field; this can be seen in the deflection of a compass needle placed near a wire through which a direct and steady current is flowing. The force of the magnetic field is at right angles to the direction of current flow. Michael Faraday in 1822 demonstrated the reverse of this law by showing that an electrical current can be induced by a magnetic field. A flow of electrons can thus produce a magnetic field and is also produced by a magnetic field; a magnetic field can therefore be employed as a means of controlling the movement of a flow of electrons, a process basic to the functioning of the scan motions in a video camera or monitor and also the foundation of many scan processing devices.

Electrical signals have a waveform which conveys the time limits of the event, the strength of the event and the direction of change of the event relative to a base line or reference point. The electrical signal can be graphically displayed in a number of ways.

On a fundamental level the waveform of an electrical signal is displayed as an XY plot of voltage changing through time. By convention, the horizontal or X axis represents the time dimension and the vertical or Y axis represents the voltage or signal strength. An oscilloscope is a test instrument which visually displays any electrical signal as a change in voltage through time. A waveform monitor is a specialized oscilloscope which graphically portrays the composite video signal.

In discussing a black and white video signal, the range of the video or picture portion of the entire signal provides an indication of the relative brightness or darkness of the image represented by the signal. A higher voltage level measured on the Y axis indicates a whiter portion of the image while a lower level indicates a blacker portion of the image.

The concept of graphic representation of waveforms is crucial to the understanding of an image processing system. As we will see, the time dimension or time frame of the signal may be extremely brief as in the representation of a single line of the video image which occurs in 1/15,750th of a second; the time frame may also be relatively long as in the representation of a frame of video, a collection of 525 lines which occurs in 1/30th of a second. The basic XY format can also be extended to incorporate a third parameter represented along the Z axis which can be conceived of as a vector extending out into space. This notion is important to understanding the technique of colorization. Woody Vasulka developed a technique using this type of vector diagram to locate parameters of the time frame of a video image, employing the Rutt/Etra Scan Processor. This graphic representation defines the line rate, field rate and intensity information.

A waveform can be described in terms of its shape, the number of times it repeats per time unit, its strength, placement and direction.

A waveform may begin at any point but when it returns to the point past which it started, the waveform has completed one cycle. Cycle refers to the completion of one rise, fall and return of the signal. It is important to note that the waveform may pass through a number of times the particular voltage at which it began before one cycle is completed. For example, the sine wave begins at the point exactly half way through one cycle before ending at this value at the second cycle after beginning. The time it takes for one waveform to be completed is called the period of the waveform. The term periodic refers to a waveform wherein a regular, repeating pattern is observable as the voltage changes through time; sine, square, and triangle are all periodic waveforms with specific shapes. Sine, square, and triangle are the basic waveshapes which can be combined with each other to produce complex waveforms. As we will see, the sine wave is actually the fundamental form from which square and triangle are derived.

Noise refers to a signal which is not periodic but random in nature, with unpredictably varying signal strengths; it is often defined as extraneous information present in the signal which is determined to be undesirable either through the process of comparing the signal to a reference signal or by personal decision. Noise can be manifested either aurally or visually and can also be used as a control. Snow is an example of video noise; snow is a random organization of monochromatic blotches and is part of the vocabulary of image processing because it is used as an image element in composition in much the same way that audio noise is used in electronic music composition.

The number of times a waveform is repeated per unit of time is called the frequency of the waveform; frequency then implies the speed of the signal. The number of cycles the signal completes in one second is measured in cycles per second expressed in Hertz or Hz.

The amplitude of the signal refers to the maximum strength attained by the signal. It is measured by the height of the waveform expressed to volts. The signal may have both a positive and negative voltage dimension. The reference line of zero volts is called ground. The total voltage excursion of the signal, obtained by the addition of the maximum positive and maximum negative points reached by the signal, is referred to as peak to peak voltage and is abbreviated Ppv.

The term gain defines the total peak to peak voltage excursion of a given signal and indicates the relative strength of the signal. An increase in the gain of the signal causes an increase in the signal level and conversely, a decrease in the gain results in a decrease in the signal level; gain thus equates with the amount of amplification of the signal. It expresses the ratio of the amplitude of the input signal to the amplitude of the output signal.

The term attenuate means to reduce in force or intensity; with respect to an electrical signal; attenuation refers to the lowering of the amplitude of the signal with respect to ground.

Instantaneous amplitude refers to the distance between a specific point in the waveform and the base line or ground and is expressed in volts.

The signal can be further defined by its positive and negative voltage dimension. An AC or alternating current refers to a signal which has both a positive and negative voltage dimension. An AC voltage rises to a maximum point and then falls through zero to a negative voltage level which is equal in amplitude to the maximum. A DC or direct current voltage does not change direction; the signal does not vary and is always either positive or negative. Polarity refers to the existence of two opposite changes, one positive and the other negative.

When a signal is inverted, the polarity of the signal is reversed. Positive signals become negative and negative become positive. In the case of a black and white picture signal, all the black become white.

The term bias indicates the repositioning of the signal relative to ground; the absolute amplitude and frequency of the signal are unchanged. The term phase refers to the relative timing of one signal in relation to another signal. If one signal is “in phase” with another, they both possess identical timing and have begun at the same instant.

A waveform may also be frequency and amplitude modulated. In amplitude modulation, the amplitude of the signal, called the carrier waveform is determined by the amplitude of a second control signal called the modulating signal which is input to a function generator. In this case, the frequency of the output remains the same as the normal output. The amplitude of the modulated or output signal changes in proportion to the amplitude of the modulating or control signal. In frequency modulation, the amplitude of the output signal remains the same as the normal output signal but the frequency of the output signal is determined by the frequency of a second signal, the modulating signal, which is fed into the function generator. The change in frequency of the modulated signal is proportional to the amplitude of the modulating or control signal. Modulation refers to the process of changing some characteristic of a signal so that the changes are in step or synchronized with the values of a second signal as they both change through time.

In the process of filtering, certain predetermined information is masked off, allowing a specific portion of data to pass through unchanged while the remaining is eliminated. Most commonly, filters act on frequency ranges although they can also act on amplitude ranges. Far example, a low pass filter cuts off high frequencies while passing low frequencies, while a high pass filter rejects low frequencies and passes high frequencies. The cut off frequency value can usually be controlled either by manual adjustment or with the technique of voltage control. A variable pass filter is actually a low and high pass filter working in series. The frequency range which passes is located between the cut off levels of the high pass and the low pass filter. The reverse process operates in a notch or band-reject filter. When the cut-off frequencies of both high and low pass filters connect in parallel overlap, the frequencies located between the two cut-off frequencies are rejected.

Signals can be further specified as analog or digital structures; the terms refer to ways of representing or computing changes which occur during an event. On a basic level, an analog signal is frequently explained as describing an event, a voltage far example, which continuously varies within its allowable range, ie. a thermometer. The measurement of the temperature is limited only by the resolution of the scale and how accurately the scale reading can be estimated. The position of the mercury relative to the scale markings must be estimated. Analog indicates that the signal as measured on a scale represents or is analogous to the information related by the signal. In a sense the scale represents the event. Analog devices use information which is constantly varying; within the allowable range, any value can be input or output. Conventional video cameras are analog systems; the video signal continuously varies and represents a pattern of lights and darks at which the camera points. A video monitor is also an analog device, but the representation flow is reversed in direction. The pattern of lights and darks, the image on the screen, represents a continually varying voltage, the video signal. A sine wave is also an example of an analog signal. The sinewave oscillator is an analog system which is specialized; it always produces a specific waveshape, the sine wave.

Digital signals are frequently explained as signals which describe information consisting of discrete levels or parts. Digital signals are concerned with stepped information; the change from one value to another in a waveform does not vary continuously but, with some qualification, occurs instantly. Digital devices are constructed from switches which have only two states; they are either on or off, open or closed. All of the

various voltage levels in a digital waveform must be expressible by two numbers, one representing the off, closed or low state; and the other representing the on, open or high state. One point of an event or voltage can be represented as a series of open or closed switches; the number of open and closed switches is counted, and this information is translated to one value. A number of these values can thus be constructed which will eventually plot a complete waveform. A digital waveform then has a stepped, square-edged appearance; the square wave is a simple example of this type of signal.

Several number places may be required to express a complex digital signal. If we have a number with one place and each place can only be a zero or a one, then we can use this number to express one of two states; 0 and 1. If we have two places and each place can be either zero or one, then we can express four different states: 00, 01,10, 11. The number places are called bits, a contraction of binary digits. The large number of combinations mathematically possible using only two numbers and a given number of places allows for the expression of many signals. Many electronic image processing systems have both analog and digital components and are often described as hybrid systems. It is important to note that with analog signals the waveform or one characteristic of the waveform is manipulated. With digital signals, the information about the waveform is altered and then used to reconstruct the waveform.

A signal then conveys certain information about an event. It contains a number of variables, such as frequency, amplitude or placement which can be changed and controlled.

Control over these variables is an issue central to electronic image processing. Whether achieved by manual or automatic means, control is exerted on a signal which defines an image and not the image itself. The achievement of control over the signals which define images is important to the use of electronic imaging as an artmaking medium.

A potentiometer or pot offers manual control over voltage through the adjustment of a knob. A familiar example of a pot is the volume control on a television receiver. Turning the knob results in an increase or decrease of the amplitude or the audio signal and thus an increase or decrease in signal strength or loudness. A pot allows only a continuous type of change over a signal. It is not possible to move from one discrete setting of a pot to another without proceeding through all the intervening voltage levels. On a basic level, a pot provides a method of manual control over the signal; the rate of change can be altered but is limited by the speed at which the knob can be turned by hand and the process of change is always continuous. A pot has three connection points or terminals. Two of the terminals are connected to a material which resists signal flow. The position of the third terminal, called a wiper, is adjustable along this resistive material. By changing the position of the wiper by manual adjustment of the knob, the amount of resistance to current flow is changed and therefore the signal. Frequently pots are calibrated, often by a series of relative number settings; because the change is continuous, the resolution of the scale to some extent determines the accurate repeatability of the manual setting.

Control over signal parameters can also be achieved by exerting an automatic rather than manual control over the pots. The technique of voltage control in effect allows the pots to be adjusted by another voltage rather than by hand. The principle of voltage control is the control of one voltage, often called the signal voltage, by another voltage, the control voltage. If the control voltage frequency is within the range of human hearing the signal can function both as a control voltage and as an audible sound; this dual role for signals and the resulting relationship between image and sound is a technique used frequently in electronic imaging. By use of control voltages the problem of continuously varying changes is overcome; one can move between discrete values without having to proceed through intervening values.

Control voltages can be periodic or non-periodic waveforms. Because they are signals, control voltages themselves can be processed by techniques such as mixing or filtering or can be amplitude or frequency

modulated before they are used as control signals. Control voltage signals can exert influences on audio signals, video signals or other control signals. They can be generated by voltage control modules, audio synthesis equipment, or computers.